Open University of Cyprus

Faculty of Pure and Applied Sciences

Msc on *Sustainable Energy Systems*

Thesis

Investigation of the Energy Performance
of School Buildings

Virginia Arvaniti

Thesis Supervisor
Dr. Paris Fokaides

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The current thesis is submitted to the School of Engineering in partial fulfillment of the requirements for the degree of Master of Science in Sustainable Energy Systems for the Open University of Cyprus.

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Contents

Abstract

Aim of this project is the investigation of the energy performance of four school buildings at Anatolia College, which is a Private School in Thessaloniki, Greece in the C Climatic Zone. For this purpose we collected data for the electrical and heat consumption for the Library that apart from the books also has many computers available for the students and thus is serving different needs from the classrooms and is offering internet and printing services even during the weekends, a building with classrooms that is operating only during lesson hours, a building with the deans and secretaries offices along with some new classrooms recently constructed, and the Gym which is a quite big building that accommodates games all day and even during weekends in its indoor field and includes as well a room with fitness equipment and some showers. Then we will create tables and figures for the mean heating and electrical energy consumption that will be studied along with questionnaires filled out by students and working staff, in order to evaluate the energy performance and propose any necessary energy conservation measures for the increase of energy efficiency and the decrease of costs, without compromising the comfort level.

1. Introduction

The energy performance of a building is defined as the amount of energy actually consumed (or estimated to be necessary) to meet the different needs associated with a standard use of the building including the HVAC system (heating, ventilation, and air-conditioning), lighting and the supplying of hot water(DHW). As a matter of fact, the energy consumption for a residence depends on many aspects including the climate, age and size of the building, heating type, socio-economic parameters that include efficiency features, management, operation and monitoring, and occupant behaviour. Where the occupant behaviour refers to their personal control over the internal temperature, ventilation, air conditioning, lighting, equipment and domestic hot water, which should not be taken into account when dealing with school buildings, since its occupants are the students who are not in charge of all the previously mentioned.

In this project we are going to investigate the energy performance of a Private School in the C climatic zone located in Thessaloniki, Greece, and specifically the Anatolia College. The investigation will include the annual energy consumption of the school's buildings both for heating and electricity during summer and winter. We will be taking into account the age and size of the building, the year of its renovation-if any renovation has occurred, the heating type, the operating hours and the operating months. Since the school is expanded in a large area, and thus has numerous and a wide range of dwellings for different use, we will be selecting four of them, which according to our point of view are quite representative of our objectives for this thesis. More precisely, in this project we are going to involve the Library that apart from the books also has many computers available for the students and thus is serving different needs from the classrooms and is offering internet and printing services even during the weekends, a building with classrooms that is operating only during lesson hours, a building with the deans and secretaries offices along with some new classrooms recently constructed and therefore their infrastructure is based on more modern building design approaches, and the Gym which is a quite big building that accommodates games all day and even during weekends in its indoor field and includes as well a room with fitness equipment and some showers.

Picture 1. The inside and outside of the Library (Eleftheriades)

Picture 2. The outside of the White Hall

Picture 3. The outside of the Ingle Hall and specifically the part with the New Rooms (renovation 2005)

Picture 4. The inside of the Gym

For all these buildings, we have access to their electricity and oil consumption which are illustrative of the energy performance and are consequently indicative of any energy improvements that could be applied to evolve their energy performance. We are going to make graphs including the construction year, the heating floor area, the oil cost, the oil quantity, the heating energy, the cost and consumption of electricity and the total energy in KWh/m^2. Hence, we will be able to create graphs with the mean heat energy consumption and the mean electrical energy consumption. Then, we will be able to compare our results to those results that have come up from different surveys (through energy monitoring, questionnaires and the use of thermal and daylight simulation tools), so as to reach our conclusions. We are familiar with the results from those studies[i], according to which the mean annual energy consumption of schools buildings in the C climatic zone of Greece is calculated up to 150 kWh/m^2 for those type of buildings that operate around 9 months, are not equipped with cooling systems (since they are not operating during the hot summer days) and thus most of the energy is spent on heating, and the mean value for electricity consumption is roughly 14 kWh/m^2. If possible, we ourselves could also provide questionnaires to some "occupants" to evaluate their feeling of comfort during working/studying hours for more useful information.

To ensure the efficient function of a school building and the downgrading of issues that may come up with time and the use of systems, the proper and regular maintenance of the building and its systems is essential. Collection and analysis of their energy data is necessary for monitoring their energy performance and for the selection of the appropriate energy saving measures. Generally, for a school it is quite important that its occupants, i.e. the students, the teachers and the working staff, are working under comfort conditions so as to achieve knowledge under the best possible circumstances considering their social/educational character. Additionally, when we are talking about such a Private school with large spaces used by much many people, we definitely need to make sure that we are able to combine energy efficiency with comfort conditions. If the best possible results are not achieved, we could propose energy saving cost effective measures relative to the implementation of thermal insulation on the walls and rood, replacement of old windows by windows with better thermal properties, shading, passive cooling be ventilation, use of controls for lighting along with the encouragement for best management, operational procedures containing energy policy, incessant energy audits, energy monitoring, staff training and conjointly, typical and precautionary maintenance.

2. Theoretical Background – Literature Review

School buildings constitute an important part of non-residential building stock, because students and teachers spend much time in these spaces. Hence it is quite important to evaluate their energy performance for the main goals to be achieved, which are the increase of energy efficiency and the decrease of costs. The decrease of costs is self-evident why it is preferable, while the importance of energy efficiency on the other hand can be explained on the basis that reducing energy waste is the fastest, most hygienic, and usually the less expensive way to provide more energy, reduce pollution and environmental degradation, slow global warming, and increase economic and national security. So energy efficiency means using less energy to perform the same amount of work and according to the International Energy Agency (IEA), who had a significant role in the Paris Agreements memorial, “Energy efficiency is the one energy resource that all countries possess in abundance”. Further, Dr Fatih Birol, the IEA Executive Director added, “I welcome the improvement in global energy efficiency, particularly at a time of lower energy prices. This is a sign that many governments push the energy efficiency policies, and it works.” It is even suggested that the implementation of energy efficiency in all possible things can help reduce carbon emissions by over 10% by 2020. According to the IEA, efficiency standards now cover 30% of energy use globally. Over a third of all emissions reductions needed to reach climate goals by 2040 must come from energy efficiency policies. In addition to switching to low-carbon energy sources and employing energy conservation strategies, energy efficiency is a key way to reduce CO2 emissions. The current worldwide mix of energy resources is weighted heavily toward oil, coal, and natural gas. In addition to emitting greenhouse gases, these resources are non-renewable, i.e. their quantities are limited or they cannot be replaced as fast as they are consumed. Though estimates regarding the remaining quantity of these resources vary, it is clear that the current reliance on non-renewable energy sources is not sustainable and involves increasingly destructive extraction processes, uncertain supplies, escalating market prices, and national security vulnerability. Accounting for approximately 40% of the total energy used today, buildings are significant contributors to these problems.

As mentioned previously, the energy performance of a building is defined as the amount of energy actually consumed (or estimated to be necessary) to meet the different needs associated with a standard use of the building including the HVAC system (heating, ventilation, and air-conditioning), lighting and the supplying of hot water(DHW). By providing knowledge on how schools consume their energy, we could enrich the awareness of school managers about the importance of improving energy efficiency and reducing energy costs. According to the EU-28, the educational buildings energy consumption accounts for the 12% of the building sector (Laustsen, Ruyssevelt, Staniaszek, Strong, &Zinett, 2011). Thus, improving the energy performance of the European building stock constitutes an effective way to alleviate the EU energy imports dependency and meet the EU targets to 2020 (European Commission, 2010).

For a proper learning environment, school buildings require optimized indoor environmental conditions, including thermal comfort, indoor air quality, lighting and a quiet atmosphere. In general, energy consumption increases with indoor environmental comfort requirements, which lead to an increase in energy costs of school buildings (Becket, Goldberger, &Paciuk, 2007, Hong, Paterson, Mumovic, &Steadman, 2014). Because of the high energy costs, schools should manage their buildings by taking energy efficiency measures into consideration to reduce operational costs and provide suitable indoor environmental conditions to the occupants (Dimoudi and Kostarela, 2009; Escriva-Escriva, 2011).

Profoundly, from all the previous, the awareness of the energy consumption patterns of a building is crucial for any comparative analyses and benchmarking of the actual consumption of individual buildings against other of the same typology using energy performance indicators (Sekki, Airaksinen, &Saari, 2015; Thewes, Maas, Scholzen, Waldmann, &Zurbes, 2014). Furthermore, this is quite favorable towards discovering whether the buildings are complying with energy requirements and being in need of a wider energy diagnosis (Corgnati, Corrado, &Filippi, 2008).

Quite clearly, the environment where children are spending most of their time during a day, is absolutely necessary to provide comfort conditions since kids are particularly sensitive to poor indoor environments while staying in school buildings along the major period of their growing up years. And since they are physically in development during those years, they are the ones who suffer the most the consequences of a poor indoor environment (REHVA, 2010); with one of the consequences being a noticeable increase in student absenteeism, onward with what this brings along for their health and educational progress.

Since the assessment of the school building's energy savings potential is important, to quantify the energy consumption and propose energy saving measures, we should understand the energy consumption patterns and identify the major energy consumers, obtain information about indoor climate conditions and identify any obstacles to be overcome, so that finally we can propose appropriate and relevant energy conservation measures (ECMs).

On the other hand, a high-performance school also has a great educational value, since it can serve as an educational tool for teaching students and the community about the importance of energy efficiency and how to educate environmentally-aware citizens. By the term "high-performance" building we mean one that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life-cycle performance, and occupant productivity. The impact of lifestyle pattern on energy consumption and carbon emissions has already increased and is a phenomenon that shouldn't be surpassed by an educational unit.

However, along with the development of the world in general, comes the degradation of the environment from the search of a higher quality of life style and the need for well-being. Historically, it has been the developed countries that have accounted for high levels of energy consumption. Yet, overpopulation and urbanization, have led to the increase of per capita emissions in both developing and developed countries.

According to the report for policy-makers approved by the Intergovernmental Panel on Climate Change (IPCC) Working Group III, "Changes in lifestyles and consumption patterns that emphasize resource conservation can contribute to developing a low-carbon economy that is both equitable and sustainable". And according to the World Wildlife Fund, an average US citizen requires 10 hectares of the planet to support his/her lifestyle, while an average European needs over five hectares. Lifestyles in the modern cities of the developing countries are becoming energy intensive and people are being conspicuous and over-consumptive.

To make a long story short, people are most of the times not willing to give up or compromise their comfort level in favor of the environment. Those who already live with lifestyle are mainly unwilling to do so, and those who don’t are actually craving it. Yet, this is exactly what should come to an end. The modern lifestyle should not be accompanied with thoughtless energy consumption, because this would lead to total disaster and that’s exactly why all these derivatives have occurred to set energy goals to be achieved by 2020 and 2040 for the earth’s sake. Moreover, thoughtless energy consumption should not be supported by the energy consumption pattern of the Private School of our project, since it is promoting values and in general it is trying to make a difference in the world by leaving a positive impact and contributing against anything disastrous. As follows, studying the energy performance of Anatolia will give us a clear view of the energy patterns and will provide us the opportunity to analyze the ways it consumes energy and therefore, the opportunity to propose energy conservation measures without compromising the comfort level and indoor quality.

3. Methodology

In this project we are going to investigate the energy performance of a Private School in the C climatic zone located in Thessaloniki, Greece, and specifically the Anatolia College. More precisely, in this project we are going to involve the Library that apart from the books also has many computers available for the students and thus is serving different needs from the classrooms and is offering internet and printing services even during the weekends, a building with classrooms that is operating only during lesson hours, a building with the deans and secretaries offices along with some new classrooms recently constructed and therefore their infrastructure is based on more modern building design approaches, and the Gym which is a quite big building that accommodates games all day and even during weekends in its indoor field and includes as well a room with fitness equipment and some showers. For all these buildings, we have access to their electricity and oil consumption which are illustrative of the energy performance. We are going to make graphs including the construction year, the heating floor area, the oil cost, the oil quantity, the heating energy, the cost and consumption of electricity and the total energy in KWh/m^2. Hence, we will be able to create graphs with the mean heat energy consumption and the mean electrical energy consumption.

Heating energy			Electricity			Total		
Building type	Construction year	Heating floor area (m^2)	Oil cost (Euro)	Oil quantity (kg)	Heating energy (kWh/m^2)	Cost (Euro)	Consumption (kWh/m^2)	Total energy (Kwh/m^2)
Library								
White								
Ingle-New rooms								
Gym								
Total mean consumption		…				…		…

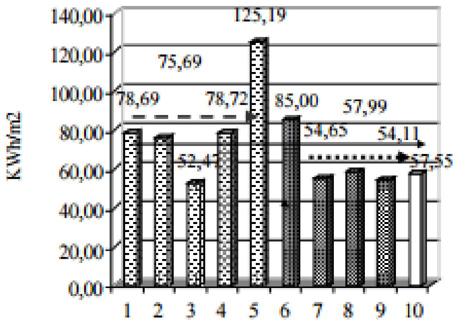


Fig.1: Indicative sample graph of the mean heating-electrical energy consumption in the four buildings

Moreover, we are willing to provide questionnaires to groups of people spending their day in these buildings so as to further contribute with their answers.

4. Applying the data through the methodology

According to the Regulation of the Energy Performance of the Buildings (KENAK), the energy performance of buildings is defined through the methodology that includes the following clues:

1. The use of the building, the desirable conditions of the internal environment (temperature, humidity, ventilation), the characteristics of the use and the number of users.

2. The climatic data of the area around the building (temperature, relevant and absolute humidity, wind's speed and solar radiation).

3. The geometrical characteristics of the building's structural elements (shape, transparent and non-transparent surfaces, shades, etc.) in accordance with its orientation and the characteristics of the internal structural elements (separations, etc.).

4. The thermal characteristics of the building's structural elements (thermal permeability, thermal mass, solar radiation absorbance, permeability, etc.).

5. The technical characteristics of the thermal installation within the spaces (the type of the system, the distribution net, the system's performance, etc.).

6. The technical characteristics of the cooling installation within the spaces (same as for the thermal installation).

7. The technical characteristics of the mechanical ventilation installation.

8. The technical characteristics of the DHW installation.

9. The technical characteristics of the lighting installation for the tertiary sector buildings and

10. The passive solar systems.

Therefore, to successfully evaluate the energy performance of the chosen building, once the data is collected from the appropriate authority, i.e. the team assigned for this evaluation, one must consider the relevant data accordingly.

The energy consumption of school units, regardless of the education level (primary, secondary) based on previous surveys carried out in school units around Greece, is illustrated in the table below. School buildings in Greece consume electrical energy mainly for artificial lighting and nowadays for the use of technology (for example computers).

Region / Climate zone	Year of research	No of buildings	Mean heating energy (kWh/m^2)			Mean electrical energy (kWh/m^2)
All Greece [1]	1993	238		67	Difference 40%	26
All Greece [3]	2006	340		68		27
Evros / C Climate zone [4]	2001-2005	10 primary Schools	No-insulated 89.4	72.8 Insulated 56.65	Difference 37%	8.65
Grevena / D Climate zone [5]	2004	9	No-insulated 139	123.31 Insulated 115.38	Difference 17%	14.31
Kozani / D Climate zone [6]	2003-2007	11 nursery 10 primary		135.9 105.8		7.5 9.3

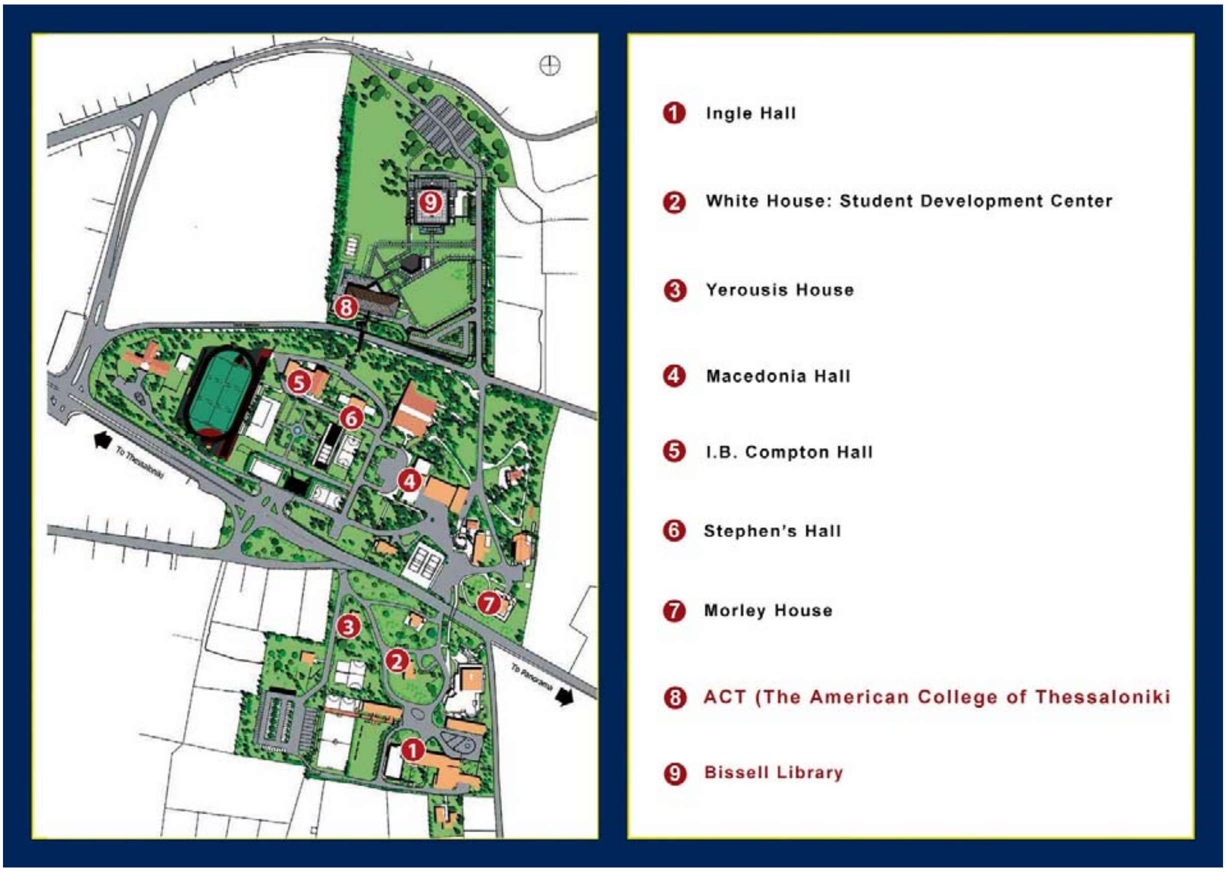
Table 1. Mean annual energy consumption in school buildings in Greece [1]

The mean annual energy consumption of school buildings in Greece is $93KWh/m^2$ and although it is lower than in other building categories, the overall energy consumption at national level is considered high because of the big number of school units, along with the fact that they mainly operate during the heating period (almost 9 months) and thus they are not equipped with any cooling systems spending most of the energy for heating.[2]

Our survey was conducted, as mentioned before, at the Anatolia College of Thessaloniki, Greece, at four of its buildings. Two of them, the Gym and the Ingle Hall, used to have pumps that operated all the time to send the hot air to the roof in the first place, from where it was then transferred to the rest of the space so as to warm the room, until in November 2013 they were replaced with new heat pumps that reduced the

[1] http://www.ep.liu.se/ecp/057/vol8/013/ecp57vol8_013.pdf
[2] http://www.ep.liu.se/ecp/057/vol8/013/ecp57vol8_013.pdf

costs as follows: Such a pump, during summer, is performing to draw the heat from the inner space and expel it to the environment (cooling the inner space), while on the other hand, during winter, it reverses its operation by drawing heat from the environment and channelling it to the inner space to warm it. This way the pump uses the environment to heat or cool the room and the use of electrical energy is necessary only during the heat pumping and so the user pays only this relevant cost. Also, in 1997 both the Ingle and the White Hall were insulated with bricks.



Picture 5. The Anatolia College campus

Thus, in addition to these, for all the four buildings we have gathered the following data, for the operation during a whole year (2013-2014, winter and summer):

Heating energy						Electricity	Total		
Building	*Construction Year*	*Heating Floor area (m^2)*	*Oil cost (Euro) (1,08€/ Kg)*	*Oil Quantity (kg)*	*Heating Energy (KWh/ m^2)*	*Consumption (KWh/m^2)*	*Total Energy (KWh/ m^2)*	*Total energy in KWh for all the m^2*	*Cost (Euro) For 0.15€/KWh*
Library	1987	1.650	9.514,8	8.810	63	8	71	117.150	17.572,5
White Hall	1962	820	4.757,4	4.405	63,4	1,707	65,107	53.387,74	8.008
Ingle Hall	1952/2005	3.474	12.559,5	11.629,2	40	14	54	187.596	28.139,4
Gym	1974	1.500	7.745	7.171,34	56,4	8	64,4	96.600	14.490

Table 2. Data of the four Anatolia buildings

Where, the above table was created according to the following calculations:

<u>For the Library</u>

Oil quantity= $\frac{total\ oil\ cost}{oil\ cost\ per\ kg}$= $\frac{9.514{,}8\text{Euro}}{\frac{1{,}08Euro}{Kg}} = 8810kg$

Heating energy= $8810kg * \frac{11{,}8KWh}{kg}$ =103958KWh and $\frac{103958KWh}{1650m^2} = 63\,\frac{KWh}{m^2}$

Consumption= 2200KWh/month*6months (summer)= 13200KWh and $\frac{13200KWh}{1650m^2} = 8\,\frac{KWh}{m^2}$

Total energy= Heating energy + Consumption= 63+ 8=71 $\frac{KWh}{m^2}$

and 71$\frac{KWh}{m^2}$ * 1650m^2=117150KWh, thus the cost=117150KWh*0.15€ per KWh=17572,5€.

For the White Hall

Oil quantity= $\frac{total\ oil\ cost}{oil\ cost\ per\ kg}$= $\frac{4.757{,}4\text{Euro}}{\frac{1{,}08Euro}{Kg}} = 4405kg$

Heating energy= $4405kg * \frac{11{,}8KWh}{kg}$ =51979KWh and $\frac{51979KWh}{820m^2} = 63{,}4\frac{KWh}{m^2}$

Consumption= 350KWh/month*4months (summer-the building doesn't operate longer than 4 summer months)= 1400KWh and $\frac{1400KWh}{820m^2} = 1{,}707\frac{KWh}{m^2}$

Total energy= Heating energy + Consumption= 63,4+ 1,707=65,107 $\frac{KWh}{m^2}$

and 65,107$\frac{KWh}{m^2}$ * 820m^2=53387,74KWh, thus the cost=53387,74KWh*0.15€ per KWh=8008€.

For the Ingle Hall

Oil quantity= $\frac{total\ oil\ cost}{oil\ cost\ per\ kg}$= $\frac{12.559{,}5\text{Euro}}{\frac{1{,}08Euro}{Kg}} = 11629{,}2kg$

Heating energy= $11629.2kg * \frac{11{,}8KWh}{kg}$ =137224,56KWh and $\frac{137224{,}56KWh}{3474m^2} = 40\frac{KWh}{m^2}$

Consumption= 8108,7KWh/month*6months (summer)= 48652KWh and $\frac{48652KWh}{3474m^2} = 14\frac{KWh}{m^2}$

Total energy= Heating energy + Consumption= 40+ 14=54 $\frac{KWh}{m^2}$

and 54$\frac{KWh}{m^2}$ * 3474m^2=187596KWh, thus the cost=187596KWh*0.15€ per KWh=28139,4€.

<u>For the Gym</u>

Oil quantity= $\frac{total\ oil\ cost}{oil\ cost\ per\ kg}$= $\frac{7.745\text{Euro}}{\frac{1{,}08 Euro}{Kg}} = 7171{,}34kg$

Heating energy= $7171{,}34kg * \frac{11{,}8KWh}{kg}$ =84622KWh and $\frac{84622KWh}{1500m^2} = 56{,}4\frac{KWh}{m^2}$

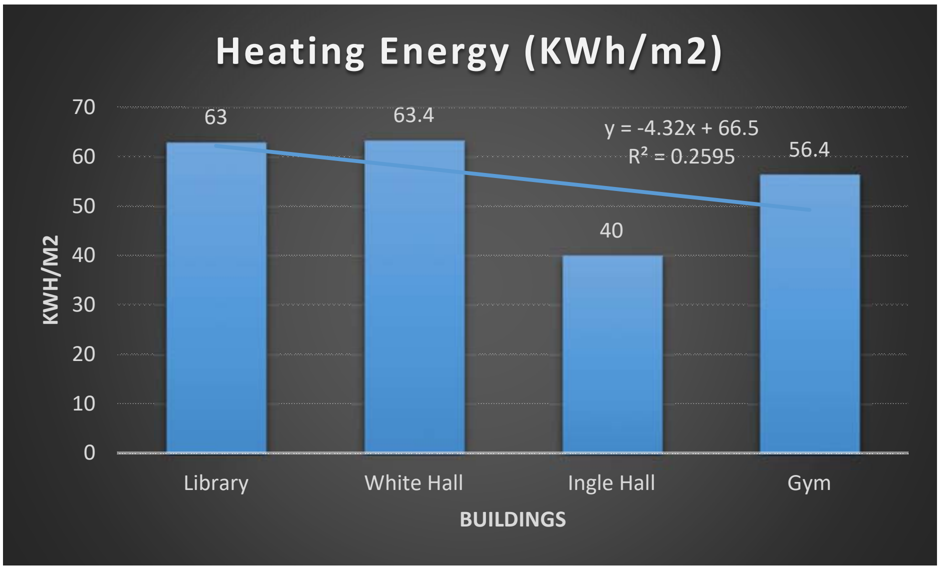
Consumption= 2000KWh/month*6months (summer)= 12000KWh and $\frac{12000KWh}{1500m^2} = 8\frac{KWh}{m^2}$

Total energy= Heating energy + Consumption= 56,4+ 8=64,4 $\frac{KWh}{m^2}$

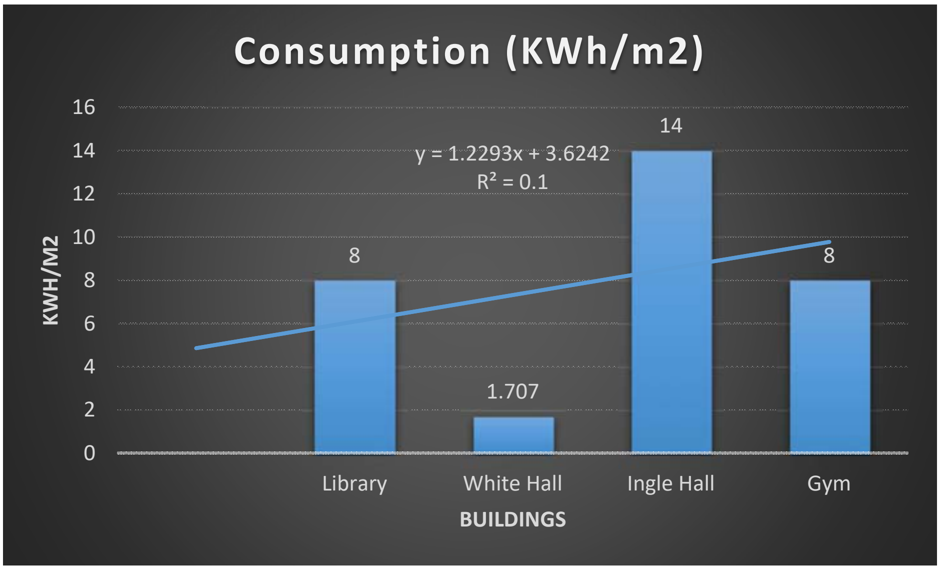
and 64,4$\frac{KWh}{m^2}$ * 1500m^2=96600KWh, thus the cost=96600KWh*0.15€ per KWh=14490€.

- The mean heating energy is 55,7$\frac{KWh}{m^2}$, the mean consumption is 7,92675$\frac{KWh}{m^2}$ and the mean total energy is 63,62675$\frac{KWh}{m^2}$ or 113.683KWh

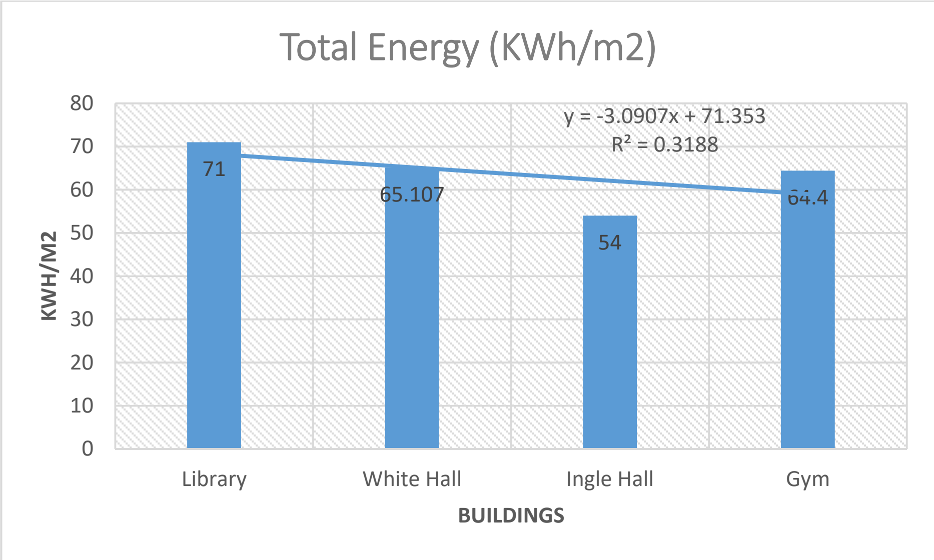
Thus, we can create the following graphs that illustrate our results from table 2:



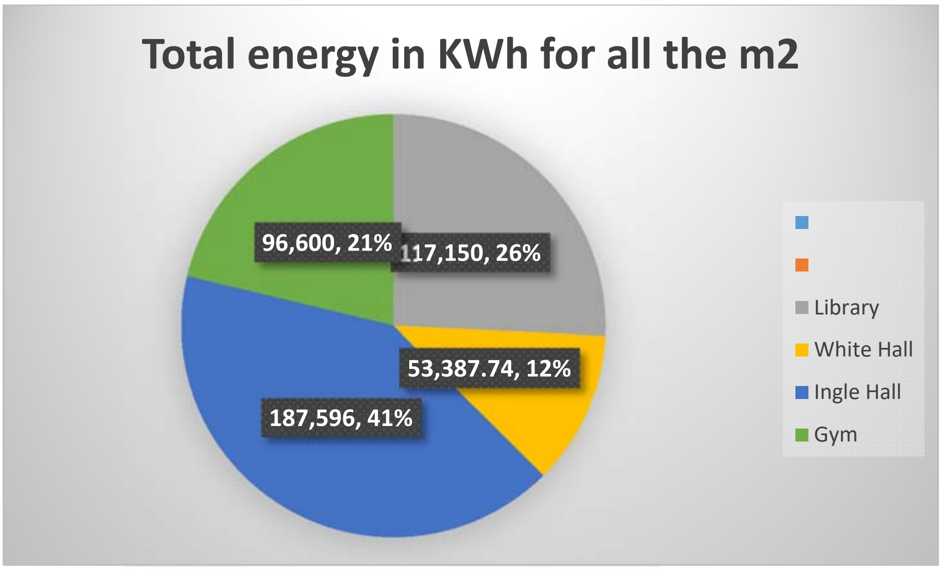
Graph 1. The heating energy for the four Anatolia buildings



Graph 2. The consumption for the four Anatolia buildings



Graph 3. The total energy (in KWh/m^2) for the four Anatolia buildings



Graph 4. The total energy (in KWh and percentages) for the four Anatolia buildings

5. Results and discussion

- From the first graph (#1) it is clear that the Library and the White Hall have almost the same heating energy consumption in KWh/m^2, although they were built around 25 years apart and they have a total of 830m^2 difference. They both consume 63KWh/ m^2 each despite the fact that the White Hall was insulated with bricks in 1997 and has a smaller surface. This probably has to do with the fact that White was constructed in 1962, 25 years before the Library, thus the material used were not as efficient as the ones used for the Library. Perhaps before the insulation in 1997, the consumption was bigger for so much smaller heating floor. It is then following the Gym that was built in 1974 and has a heating floor area of 1500m^2. According to the employees of the school, there has been a reduce in heating cost up to 23.000€, due to the fact that they started using those heat pumps (mentioned before) from 2013 and additionally managed to separate the area where the games took place from the bleachers.
  And in the end we have the Ingle Hall with quite a different consumption, up to 40 KWh/m^2, 23 less than the two first and 16 less than the Gym. Obviously, the insulation with bricks in 1997, the construction of the new rooms in 2005 with the latest technology and the use of the new heat pumps, has been a success.
- The second graph (#2) shows us that the consumption is the smallest for the White Hall, which was expected since this building only has teaching classes and thus the only electricity consumed is the one used for lighting and this only during the school hours. On the contrary, around 8 times bigger is the consumption for the Library and the Gym, with the Library having to facilitate all the computers apart from the lighting of its inner space and the Gym having to operate during weekends and nights (where more and sufficient lighting is required) for all the games taking place. We would like to add here that the Gym can be rent for games from individuals outside the school that would like to practise their sport there or play their game there, and also from sports clubs from all over the world for any sport event. Also, it has a Domestic Hot Water (DHW) system required for use in the showers and toilets.

At the top of the consumption is the Ingle Hall, that not only has to provide electricity for the lighting of the classrooms and the deans offices, but also and most importantly, for the kitchen which operates both during the school hours to provide food to the teachers and students, and during the afterschool hours to make food for the boarding school which is also accommodated in the same building. There are up to 40 children staying at the boarding school during their academic years spending all their days there and consuming energy for all their daily needs.

- And finally, in the third graph (#3) we can see the total energy that comes up if we add the heating energy to the consumption. The Library, as expected, has the biggest total energy consumption due to the highest heating energy and the quite big electricity consumption. Further, from the last graph (#4) we can see that the Ingle Hall is consuming the highest percentage of KWh of the total energy (41%) for its operation during the school year, which was also expected by taking into account the kitchen, the classrooms, the deans offices and the boarding school, accommodated all under the same roof.
- However, the mean total energy consumption for all these four buildings is around 64 KWh/m^2, with 92KWh/m^2 being the mean annual energy consumption of schools in Greece. Therefore, we are talking about 28KWh/m^2 less than the average in Greece. Yet, there are measures that can be suggested to reduce the heating energy or the consumption and thus further reduce the total energy and the costs.
- There are air conditions in the deans' offices and in the other offices (where employees that aren't teachers are spending most of their time) and in the Library as well, but there aren't any in the classrooms. There also aren't any cooling fans in the ceilings, but floor fans can be provided and used per request.
- The White Hall's classrooms don't have any shading apart from the windows' curtains.
- Classes don't happen during Christmas and Easter holidays, thus the consumption during those weeks is lower since there are much less needs for heating and electricity for lighting and equipment operation.

- Moreover, school is closed during the hot summer days so there is also less need for cooling during its operation. Thus, schools present lower heating and cooling needs during peak demand periods which usually coincide with school holidays.

On the overall, we are talking about buildings up to 30 years old, for which any changes towards a better energy performance, consider only renovations or refurbishments and are far from reconstruction or rebuilding. Therefore, we have to take into account what could happen to the already existing buildings to help improve energy saving along with thermal comfort measures, for these school units in the C climatic zone specifically. According to relevant data, up to 60% of the schools existing in Greece are up to 30 years old, with only 40% being relatively newly constructed, after 1985 (in the case study of Anatolia, from the four chosen buildings, only one-the Library- is constructed after 1985). So base on the construction type of the building and the climatic zone to which it belongs, there is obviously different energy consumption for heating, as illustrated in the table below:

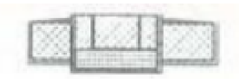
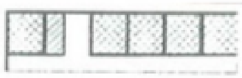
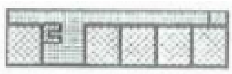
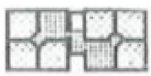
School Type	Schematic layout	Year of construction	Energy consumption for heating kWh/ m2		
			Climatic zone A	Climatic zone B	Climatic zone C
Old stone building		Before 1960	10	48	146
Type with open corridor		1960-1980	15	46	122
Type with closed corridor		After 1980	12	41	115
Type ATHINA		After 1980	5	27	86

Table 3. School types and energy consumption for heating [3]

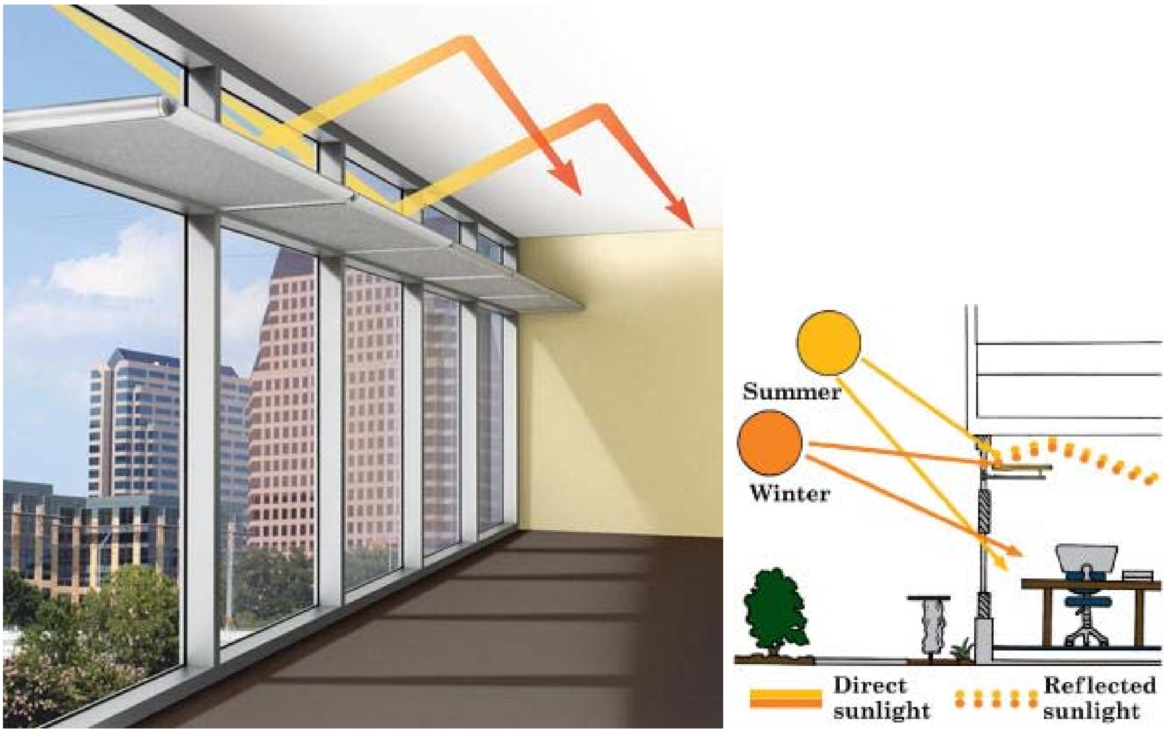
As mentioned before, the mean annual energy consumption of Schools in Greece is 92KWh/m^2 occurring, based on data from a 1995 study in a sample of 238 school buildings across Greece, from an average energy consumption of 66KWh/m^2 for heating, 2KWh/m^2 for cooling, 16KWh/m^2 for lighting and 8KWh/m^2 for the use of various

[3] https://www.sciencedirect.com/science/article/pii/S1878029617301111

devices. So, most of the energy is used for heating, which makes sense considering that the school operates during the colder months. However, the fact that only 2KWh/m^2 are used for cooling implies a low energy consumption but doesn't secure the relevant comfort of the "occupants". So this means that relevant cooling measures could also be suggested so as to avoid extra energy consumption but simultaneously provide more comfort to the students, the teachers and the rest of the employers.

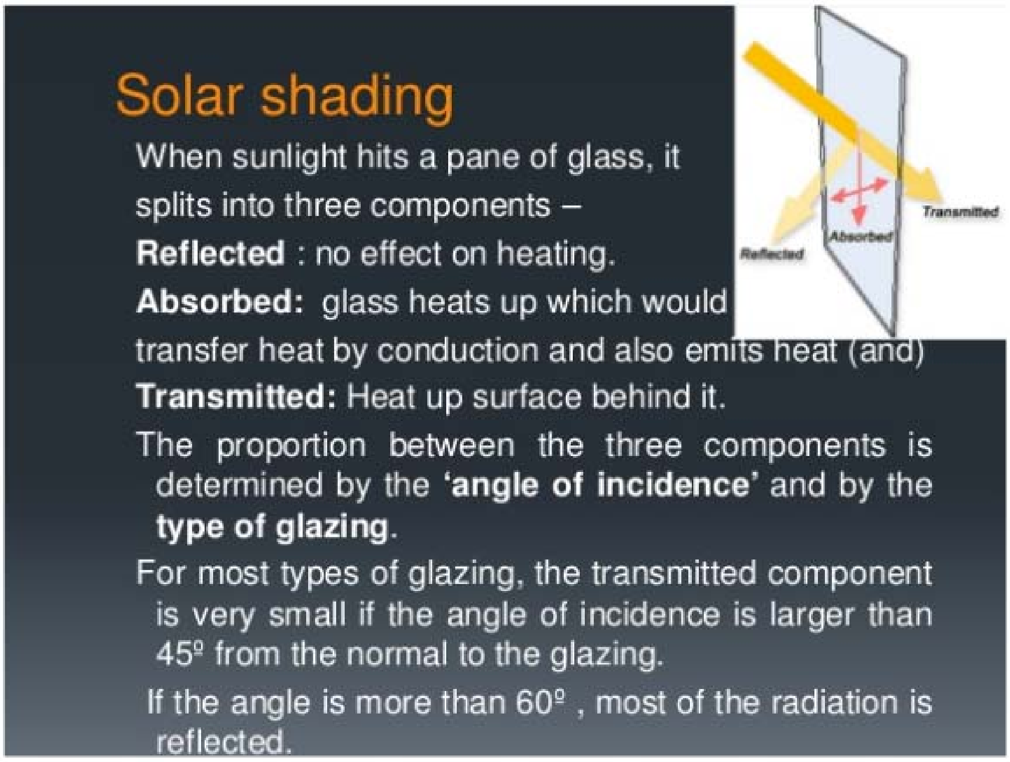
Taking into account that the windows applied to the four buildings are already replaced by ones with better thermal properties saving a 7% of thermal loads and the fact that the Ingle and the White hall are already insulated with bricks, we could further suggest the insulation of the wall for the rest of the buildings along with the roof's insulation (with a cost of 21€/m^2), which both can reduce up to 14% the thermal consumption. Also passive cooling by ventilation and ceiling fans, if they don't already exist, could further induce the cooling loads that lead to energy consumption. It is not to be ignored the fact that the most cost effective measures are those related to the improvement of the performance of the existing heat production and distribution systems, rather than those related to the building fabric.

Moreover, we could install some shading devices (like in the White Hall) but we've got to be careful with their installation since not moveable shading devices in non-favourable orientations don't have positive effect in winter solar gains, while moveable shading devices, that would be much more effective, have quite a high cost. Likewise, in accordance to daylight issues, the solution that could be combined with the use of the already existing curtains and/or the window blinds, is the implementation of light selves in southern elevations along with external louvers that can double the daylight resulting in near the windows and quadruple in bigger distances thus reducing the heating and cooling loads needed. Light shelves, curtains and window blinds (venetians, blackout, pleated, roller and vertical louvre) are all solar shading devices, either internal or external or interpane, i.e. between the internal and the external building space. Such devices prevent the sun light either by blocking it or allowing part of it, etc. from occurring on a building and can be manual, fixed or automatic moveable. The solar shading is important to reduce heat during summer and promote it during winter while also reducing the HVAC loads and consequently reducing costs while improving the building's energy performance.



Picture 6. Light shelves.

Their way of operating is illustrated in the picture below:



Picture 7. Solar shading.

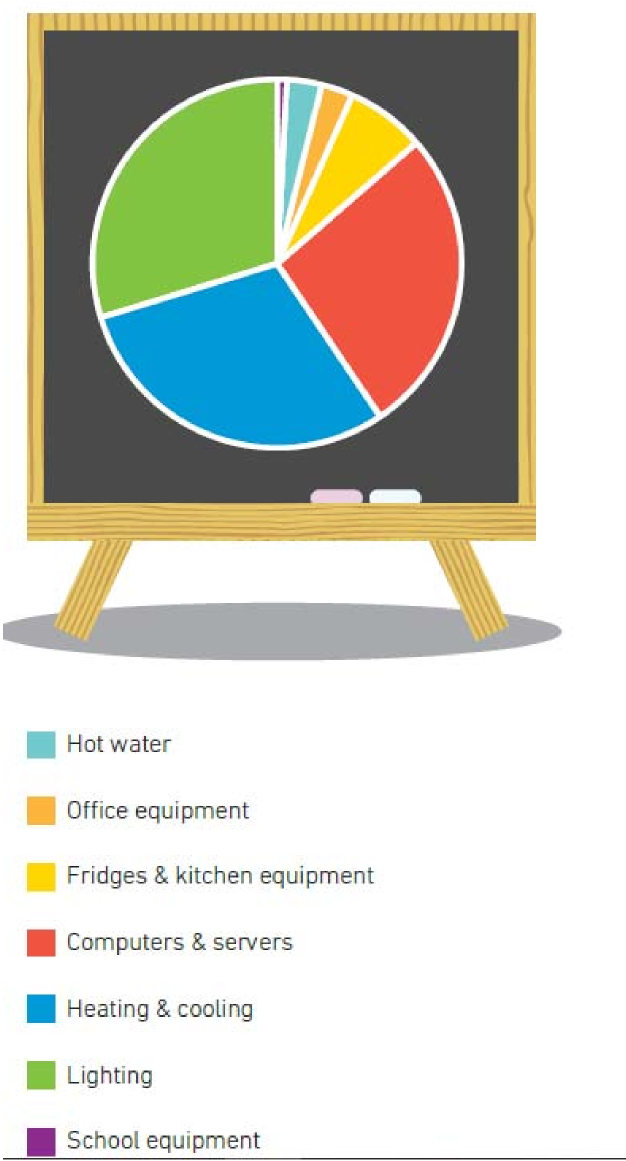
To select the proper shading device one has to be advised by this table:

Orientation	Suggested Shading Type
North	fixed or adjustable shading placed horizontally above window
East and West	adjustable vertical screens outside window
NE and NW	adjustable shading
SE and SW	planting

Climatic zones	Requirements
Hot and dry	Complete one year round shading
Warm and humid	Complete year round shading , but design should be made such that ventilation is not affected
Temperature	Complete year round shading but only during major sunshine hours
Cold and cloudy	No shading
Cold and sunny	Shading during summer months only
Composite	Shading during summer months only

Table 4. Select shading type and category.

Summing up, as the main areas of energy consumptions in schools include lighting, heating, cooling and computers, with a typical school's energy consumption presented in the image below:



Picture 8. Typical school's energy consumption.

It becomes clear that even the simplest actions can result in significant cost savings that not only benefit the school financially, but also have social and environmental impacts along with the also important fact that students, teachers and parents acknowledge everything around climate change thus become active citizens that can prevent other environmental issues our communities are faced with. Therefore, alongside with the previously mentioned measures, it is also important that there is daily and/or online energy observation so as to conclude whether there is any overconsumption or unnecessary use or anything that could happen differently in order to consume less, without having to wait for the bills to be informed by this data. Further, the school can reduce the after school usage of energy that is the result of non-productive consumption that could be saved by simply turning off all lights and all the devices (computers, printers, photocopiers) and office equipment, that even when left at the standby power, they consume the necessary energy that keeps them ready for use. So it is more appropriate for the devices to be switched off and even unplugged. It would also be a benefit if the school organized campaigns to promote energy saving and raise awareness by encouraging everyone to play their part.

Concerning lighting, the instalment of energy efficient lighting would be another simple way to help reduce relevant cost and consumptions. This could happen by replacing the common light bulbs, in the classrooms and the gym, with T5 or LED fittings that could provide up to 50% reduce in consumption. Besides, movement and daylight sensors could offer an even better solution while they operate when necessary and prevent energy waste.

Concerning heating and cooling, what could be useful is the daily and monthly set of heating during school hours to match how much heat is needed during the day with the relevant hours, and review the setting often to make sure it’s correct. Also, there could be installed timers on air conditions along with limits on the highest and lowest temperature to prevent over-heating and over-cooling as a thoughtless usage.

Finally, a simple and yet useful measure, could be the installation of automatic door closers, since doors left open can be a significant source of heat loss during winter.

Below, it is presented a table of the actions that could be taken along with the ones responsible for them in order to promote energy saving:

Who can do what?

Actions	Principal	Teacher	Parent	Student	Bursar/ Administrator	Maintenance officer	Energy/ Sustainability Co-ordinator
Essential							
Policy and planning	**✔**	✔	✔		✔		✔
Identify responsibilities/ energy team	**✔**						
Leading role in Whole School Approach	✔	**✔**					
Identify curriculum opportunities		**✔**					✔
Raise awareness of staff and pupils	✔	✔		✔	✔	✔	**✔**
Active participation in no cost measures		✔		**✔**	✔	✔	✔
Read meters regularly						**✔**	✔
Record/ analyse/monitor energy consumption				✔	✔		**✔**
Identify areas of avoidable waste		✔		✔	✔	**✔**	✔
Review progress towards targets and benchmarks	✔		✔		✔	✔	**✔**
Desirable							
Conduct energy walk-rounds	✔	✔		✔	✔	✔	**✔**
Advise on technical measures						✔	✔
Advise on energy purchasing							
Contribute to curriculum issues	✔	**✔**		✔			✔
Identify all energy using systems/ equipment				✔		**✔**	✔
Identify controls, timers, set points						**✔**	✔
Maintenance of energy using equipment						**✔**	
Sanction appropriate investment	**✔**		✔		✔		
Apply for relevant grants	✔				✔		**✔**
Provide regular progress reports					✔		**✔**

Best suited for task (shaded; shown here as **✔**)

✔ Could do the task

Table 5. Roles and responsibilities.

6. Conclusions

Summing up, the purpose of this thesis was to investigate the energy performance of Anatolia College (a school in Thessaloniki), i.e. the amount of energy actually consumed (or estimated to be necessary) to meet the different needs associated with a standard use of the building including the HVAC system (heating, ventilation, and air-conditioning), lighting and the supplying of hot water (DHW). Anatolia College is a public school expanded in a wide area with many buildings that accommodate classrooms, offices and other facilities that operate throughout the day and/or even during weekends. We chose a school building because school buildings constitute an important part of non-residential building stock since students and teachers spend much time in these spaces. Hence it is quite important to evaluate their energy performance for the main goals to be achieved, which are the increase of energy efficiency and the decrease of costs. For this to occur, even the simplest actions can result in significant benefits. Since Anatolia is expanded in a large area, and thus has numerous and a wide range of dwellings for different use, we have selected four of them, which according to our point of view are quite representative of our objectives for this thesis. We took into account the age and size of the building, the year of its renovation-if any renovation has occurred, the heating type, the operating hours and the operating months and constructed a table including the construction year, the heating floor area (m2) , the oil cost (1,08€/Kg), the oil quantity (kg), the heating energy (KWh/m2), the consumption of electricity along with the total cost (0.15€/KWh) and energy (KWh). From the data of this table we created graphs that were indicative of the mean electrical and heat energy consumption so as to compare them with the standards provided by other studies and acknowledge the areas that needed to be improved in order to have better relevant results.

Towards this direction, we found helpful the insulation of the wall for some of the buildings along with the roof's insulation (with a cost of 21€/m2), which both can reduce up to 14% the thermal consumption. Also passive cooling by ventilation and ceiling fans, if they don't already exist, could further induce the cooling loads that lead to energy consumption along with the installation of some shading devices. Likewise, in accordance to daylight issues, the solution that could be combined with the use of the already existing curtains and/or the window blinds, is the implementation of light selves in southern elevations along with external louvers that can double the daylight resulting in near the windows and quadruple in bigger distances thus reducing the heating and cooling loads needed.

Further, the school can reduce the after school usage of energy that is the result of non-productive consumption that could be saved by simply turning off all lights and all the devices (computers, printers, photocopiers) and office equipment, that even when left at the standby power, they consume the necessary energy that keeps them ready for use. It would also be a benefit if the school organized campaigns to promote energy saving and raise awareness by encouraging everyone to play their part.

Concerning lighting, the instalment of energy efficient lighting would be another simple way to help reduce relevant cost and consumptions and concerning heating and cooling, what could be useful is the daily and monthly set of heating during school hours to match how much heat is needed during the day with the relevant hours, and review the setting often to make sure it’s correct.

Finally, a simple and yet useful measure, could be the installation of automatic door closers, since doors left open can be a significant source of heat loss during winter.

It is important to evaluate and improve the energy performance of a school building since it is a place where children spend many hours during the period when they are physically in development and we are aiming at their most successful health and educational progress. Further, the teachers and the rest of the employees also need to enjoy comfort conditions in order to best perform. Also, the costs are lowered leading to financial savings and towards achieving greater results that further apply to the protection of the environment as well, while promoting environmentally friendly behaviour and cultivate green approach. Moreover, this way we can provide more energy, reduce pollution and environmental degradation, slow global warming and increase economic and national security.

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